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ABSTRACT

In a prospective longitudinal study, 1244 children who had received three neurological examinations in their first year of life were administered measures of cognitive development and academic achievement through age 12. Twenty-two Ss identified as neurologically suspect or abnormal on more than one of the infant examinations consistently performed far below control Ss on all measures, with almost one-third having Stanford-Binet IQs below 70. One-hundred and fifty-six Ss neurologically suspect or abnormal on only one infant examination performed significantly less well than 1066 Ss never suspected of neurological abnormality in infancy. Results suggested that evidence of even transitory neurological abnormality observed during the first year of life may be an indicator of risk for developmental impairment. Persistent evidence of such abnormality was found to be a strong predictor of later problems with cognitive development and school achievement. (Author/CL)

INFANT NEUROLOGICAL ABNORMALITIES AS PREDICTORS OF IQ AND SCHOOL PERFORMANCE

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Paper Presented at the Annual Meeting of

The American Psychological Association,

Toronto, August 1978

Abstract

In a prospective longitudinal study children who had received three neurological examinations in their first year of life were administered measures of cognitive development and academic achievement through age 12. Subjects identified as neurologically suspect or abnormal on more than one of the infant examinations (N=22) consistently performed far below controls on all measures, with almost one-third having Stanford-Binet IQ's below 70. Subjects neurologically suspect or abnormal on only one infant examination (N=156) performed significantly less well than subjects never suspected of neurological abnormality in infancy (N=1066).

Infant Neurological Abnormalities as Predictors of IQ and School Performance[1]

Rosalyn A. Rubin and Bruce Balow

University of Minnesota

It has long been suspected that early neurological damage may underlie later manifestations of intellectual and behavioral impairment. However, the research literature presents conflicting evidence regarding the reliability of early childhood diagnoses of neurological abnormalities as well as the predictive power of such diagnoses as they relate to later development (Balow, Rubin, & Rosen, 1976; 1977).

Results of several studies of changes in neurological status over time indicate that considerable change does occur (Donovan, Coues, & Paine, 1962; Kalverboer, Touwen, & Prechtl, 1973) even in subjects who display organic signs of severe neurological damage such as cerebral palsy (Solomon, Holden, & Denhoff, 1963). However, study findings are mixed. Knobloch and Pasamanick (1974) found in a longitudinal study that infants with neuromotor abnormalities in infancy had a higher incidence of mental retardation. In contrast, the extensive neurological examination developed by Graham (1956) enabled the differentation of infants with perinatal problems from those without such problems, but three-year and seven-year follow-ups failed to reveal

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significant relationships between the infant examinations and the occurrence of neurological, intellectual, and behavioral problems at these later ages (Corah, Anthony, Painter, Stern, & Thurston, 1965; Graham, Ernhart, Thurston, & Craft, 1962).

Conflicting findings may reflect a variety of underlying factors including varying types of examinations, examinations administered at different stages of development, transience of specific symptoms, or simply the lack of enduring effects. In this context, it may be helpful to note relatively recent changes in neurological interpretations of the significance of early brain damage.

As recently as the mid-sixties the prevailing view held that brain damage in an infant was less serious than damage in an older person. With a few significant exceptions (e.g., Hebb, 1942; 1949), it was generally assumed that since the very young brain was relatively undifferentiated and plastic, other parts of the brain would over time compensate for the injured part. During the past decade this view regarding the relative seriousness of early brain damage has been seriously challenged. In a recent review of research in this area, Isaacson (1976) noted that, contrary to earlier optimism about the plasticity of the neonatal brain, early brain damage creates permanent alterations in the structure of the brain which may have lasting behavioral effects. Isaacson further pointed out that brain damage in the adult often produces relatively specialized behavioral effects--damaging a speech center, for example, but leaving many other abilities unaffected--while brain damage in the infant, with its sequelae of aberrant cellular configurations, can produce generalized deficits in all areas.

It therefore becomes apparent that even though brain damage in an infant may produce permanent effects, specific neurological signs are not necessarily stable over time. Knobloch and Pasamanick (1974) point out that after one year the child has more control of body parts and can compensate for minor disabilities. In a study by Solomon, Holden, and Denhoff (1963) it was found that four of five cases of spastic hemiplegia identified between 12 and 18 months had completely resolved by 24 months; however, three of the four resolved cases were mentally retarded.

The purpose of the present study is to determine the extent to which early neurological examinations can effectively identify a "high risk" population which may be expected to manifest continuing developmental disabilities.

Method

Subjects

Subjects were participants in the Educational Follow-Up Study (EFS) at the University of Minnesota (Balow, Anderson, Reynolds, & Rubin, 1969; Rubin & Balow, 1977) who had also participated in the national Collaborative Perinatal Research Project (Berendes, 1966). All EFS subjects for whom results were available from three neurological examinations administered during the first year of life were included in the present investigation (N=1244, which represented 77.1% of the total EFS population). Although not initially drawn in a random fasion from the general population, the EFS population is essentially representative of the white, urban, midwestern population in terms of socioeconomic status, and is normally distributed on individual measures of intelligence (Myrianthopoulos & French, 1968; Rubin & Balow, 1977).

For purposes of the present investigation subjects were divided into three groups according to the number of times they had been identified as neurologically Suspect or Abnormal on neurological examinations administered during the first year of life.

Group I N = 1066 (85.7%) - Subjects classified as Normal on all three examinations

Group II N = 156 (12.5%) - Subjects classified as Suspect or Abnormal on one examination

Group III N = 22 (1.8%) - Subjects classified as Suspect or Abnormal on at least two examinations

An additional three subjects who were consistently classified as abnormal and whose later IQ scores ranged from 30 to 62 manifested specific syndromes from the time of birth (Down's Syndrome, Pierre Robin Syndrome, and microcephaly) which are known to be associated with severe developmental impairment and were therefore excluded from the sample.

Since data were not available for all subjects on all measures, the N's vary somewhat for different measures. Neither this difference in N's on various measures nor the large difference in sample size among the three neurological groups precludes the statistical analyses reported below, which are appropriate for the particular circumstances (Winer, 1962).

Measures

Neurological examinations were administered at the University of Minnesota Hospitals to all subjects during the neonatal period (first 48 hours), at 4 months, and again at 12 months. On each examination the physician reported his overall clinical impressions of the neurological status of the child on the basis of an extensive protocol ranging from 77 to 121 items. An additional neurological examination was administered at age 7 based on a 123 item protocol. On the neonatal exam subjects were classified as either

Normal or Abnormal. On the 4 month and 12 month examinations subjects were coded as 0=Normal, 1=Suspect, or 2=Abnormal.

Socioeconomic Status.

Socioeconomic Index. Socioeconomic index scores were computed for each subject using a formula developed by the U. S. Bureau of the Census based on parental education, occupation, and family income. This index yields composite scores on a 10 point scale from 0-9.9 with the mean for the general population falling approximately at 5.4 (Myrianthopoulos & French, 1968).

Developmental and Intelligence Quotients.

Bayley Scales of Mental and Motor Development (Collaborative Study Manual, Part III-D, 1966), administered at 8 months of age. On the Mental Scale a score of 75 or below, and on the Motor Scale a score of 27 or below, was considered suspect.

Stanford-Binet, Short Form L-M, administered at 4 years of age.

Wechsler Intelligence Scale for Children, administered at 7 years of age.

Four-Year Psychological Examination.

(1) Graham-Ernhart Block Sort. Child sorts materials which vary in color, size, and shape. Intended to discriminate between brain-damaged and non-brain-damaged preschoolers. Means given are raw scores.

(2) Gross Motor. Total, coded 1=normal, 2=suspect, 3=abnormal.

Subtests: (Coded 1=pass, 2=fail)

Line Walk. The child walks a straight line without stepping off.

Hopping. Right and left foot.

Ball catch. Child has three chances to catch a ball which is on a string and is swung so that it will strike him on the level of his breast plate.

(3) Fine Motor. Total, coded 1 = normal, 2 = suspect, 3 = abnormal.

Subtests: (Coded 1 = pass, 2 = fail)

Wallin Pegboard B (square pegs), right hand and left hand. A pass consists of replacing all pegs in less than 30 seconds on the trial for each hand.

Copy Forms. Child reproduces a circle, cross, and square.

Stringing Beads. A pass consists of more than six beads strung in the two minutes allowed.

Porteus Maze, Level IV, Cross, Vineland Revision Form. Child draws a line which remains within two parallel boundary lines.

(4) Behavior Profile. Examiner rates child's emotional reactivity, degree of irritability, cooperation, dependency, attention span, goal orientation, response to directions, activity level, rigidity-flexibility, and appropriateness of communication. Total score coded 1 = normal, 2 = suspect, 3 = abnormal.

(5) Overall Impression. Summary of 4-year psychological examination. Coded 1 = normal, 2 = suspect, 3 = abnormal.

School Readiness.

Metropolitan Readiness Test (MRT). Measures skills and abilities which contribute to readiness for initial first grade work such as auditory and visual perception, motor coordination, linguistic skills, knowledge of numbers, and ability to follow directions. Individually administered at ages 5 and 6. Means given are raw scores.

Illinois Test of Psycholinguistic Abilities (ITPA). Measures specific aspects of cognitive/language ability in encoding, decoding, associating, and sequencing. Individually administered at ages 5 and 6. Means given are language age scores.

School Achievement.

Wide Range Achievement Test (WRAT). Subtests measure word pronunciation, spelling, and arithmetic computation. Individually administered at ages 7 and 12. Means given are raw scores.

Stanford Achievement Tests (SAT). Subtests in Reading, Spelling, and Arithmetic. Individually administered at ages 9 and 12. Means given are raw scores.

Special School Services and Placements.

Through an annual questionnaire, classroom teachers were asked to identify any special school services or placements received by the study child. Data presented in Table 5 are cumulative through the end of grade six. Coded: 0=did not receive service, 1=did receive service.

Behavior Ratings by Teachers.

Each year classroom teachers were sent a questionnaire on which they were asked to indicate whether or not the child showed behavior problems in the classroom. Data presented in Table 5 are cumulative through the end of elementary school. Coded: 1=never identified as a behavior problem, 2=identified as a behavior problem by at least one teacher but not by all, 3=identified as a behavior problem by all teachers.

Procedure

Table 1 about here

As reported in Table 1, an analysis of variance of mean socioeconomic index scores showed significant differences ($p < .01$) among the three neurological groups with Group I, the normal control group, obtaining the highest

scores while Group III, comprised of subjects most frequently identified as neurologically suspect or abnormal, obtaining the lowest scores. Further analysis using the Newman-Keuls test (Winer, 1962) found significant differences between Groups I and III; however, neither group differed significantly from Group II.

Since socioeconomic status is a known correlate of the majority of measures employed in this study, e.g., IQ, language development, and school achievement (Coleman, et al. 1966; Mosteller & Moynihan, 1972), all further analyses of study data were conducted using analysis of covariance procedures with socioeconomic status as the covariate. In those instances in which the analysis of covariance revealed significant differences among mean scores, the Newman-Keuls test was used to determine the significance of the differences between pairs of mean scores included within the MANOVA.

The cumulative distributions of IQ scores for each of the neurological groups were compared using Kolmogorov-Smirnov Type tests (Conover, 1971) of the differences among distributions.

Results

Table 2 about here

As shown in Table 2 significant differences were found among the three neurological groups on the Bayley Scales of Mental and Motor Development administered at 8 months, and on 11 of 16 measures of gross and fine motor skills administered at age 4. In each instance Group I received the most favorable scores while Group III received the least favorable scores. Of the 4-year perceptual motor tasks only the three trials at catching a ball

and copying a square failed to yield significant differences. It should be noted that copying a square proved to be an extremely difficult task for all subjects, with only 20% of Group I and 11% of Group III able to successfully complete this item. The high level of difficulty may have contributed to the lack of significant differences among groups.

On the Bayley Scales, and 5 of the 19 perceptual motor measures, Newman-Keuls tests revealed significant differences between each pair of means within the MANOVA. On 9 of the remaining perceptual motor measures the significant differences found among the three groups were due primarily to the extremely low scores of Group III, which differed from both Groups I and II, while Groups I and II did not differ significantly from each other. On one measure, the Graham Block Sort, Groups II and III both differed from Group I but not from each other.

Table 3 about here

Examination of the distribution of the two sets of IQ scores presented in Table 3 reveals that on the 4-year Stanford Binet 1.0% of Group I, 1.9% of Group II, and 31.8% of Group III scored below IQ 70, while 5.2%, 1.2%, and 0% of Groups I, II, and III respectively scored above IQ 130. On the 7-year WISC, 0.7% of Group I, 1.3% of Group II, and 21.1% of Group III scored below IQ 70, while 2.6%, 0.7%, and 0% of Groups I, II, and III respectively scored above IQ 130. Analysis of covariance showed significant mean differences favoring Group I on both IQ measures and on number of subjects identified as neurologically abnormal at 7 years. At 7 years, 50% of Group III was diagnosed as definitely neurologically abnormal compared to 9.3% of Group II, and only 1.1% of Group I.

Table 4 about here

As shown in Table 4 significant differences (generally beyond the .01 level) were found among the three neurological groups on measures of school readiness and language development administered at ages 5 and 6 and on all measures of academic achievement administered at ages 7, 9, and 12.

Table 5 about here

The mean number of special school services received by subjects in the three neurological groups is reported in Table 5 along with teacher ratings of behavior. Significant differences were found in numbers of subjects receiving psychological services and special class placement as well as in total number of special services received. In each instance subjects in Group III were the most frequent recipients of special services while subjects in Group I were the least frequent recipients of these services.

Discussion

Results of this study clearly indicate that subjects identified as neurologically suspect or abnormal on more than one occasion during the first year of life constitute a high risk group for later impairment of perceptual-motor, cognitive, and academic performance. Fifty percent of such subjects (Group III) continued to show definite clinical signs of neurological abnormality upon reexamination at age 7, while an additional 13.6% were "neurologically suspect." This group also scored significantly below control subjects on all measures of cognitive development and academic

achievement through age 12. Almost one-third of subjects consistently identified as neurologically abnormal in their first year of life scored in the retarded range (IQ <70) on the Stanford-Binet administered at age 4, compared to only 1.9% of the group diagnosed as Abnormal on only one infant examination, and 1% of the Normal control group. While the incidence of neurological abnormalities was greater among lower SES subjects, highly significant differences favoring normal over neurologically abnormal subjects were consistently observed when SES was statistically controlled.

On measures of infant development, IQ, and a number of measures of academic achievement, it was found that subjects who had been identified as neurologically suspect or abnormal on only one examination, while scoring higher than those with two or more such identifications, nonetheless scored significantly lower than members of the normal control group. Therefore it appears that evidence of neurological abnormality observed at a single point during the first year of life, even if such evidence is transitory in nature, is an indicator of a population at greater risk for developmental impairment, while persistent evidence of such abnormality is a strong predictor of later impairment of cognitive development and school achievement.

Although the relationships are not strong enough to support specific individual predictions, it is nonetheless evident that a relatively high proportion of individuals identified as neurologically abnormal during the first year of life may be expected to be in need of special assistance and services by the time they reach school age.

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Table 1

Anaylsis of Variance of Mean Socioeconomic Index

Scores of Neurologically Normal and Abnormal Subjects

	Neurological Groups			
	I (N=1066)	II (N=156)	III (N=22)	
Measure	$\overline{X}$	$\overline{X}$	$\overline{X}$	p
Socioeconomic Index	5.39	5.09	4.44	.01

<u>Note</u>. I=neurologically normal; II=suspect or abnormal on one exam; III=suspect or abnormal on 2 or more exams.

Table 2

Analysis of Covariance of Mean Scores of Normal and Neurologically Abnormal Subjects on Measures of Infant Development, 4 Year Perceptual-Motor Skills, and 4 and 7 Year IQ Scores

	Neurological Groups			
	I	II	III	
Measures	X	X	X	P
8-mo. Bayley Mental	79.7	76.6	67.7	.001[c]
8-mo. Bayley Motor	34.2	31.4	27.8	.001[c]
4-yr. Psychological Examination				
Graham Block Sort	36.07[a]	34.47	30.67	.048
Gross Motor	1.08	1.14	1.68	.001[c]
Line Walk	1.06	1.12	1.28[b]	.001
Hopping-right foot	1.26	1.34	1.67[b]	.001
Hopping-left foot	1.27	1.33	1.60[b]	.011
Ball catch-Trial 1	1.42	1.45	1.58	.288
Ball catch-Trial 2	1.33	1.38	1.53	.133
Ball catch-Trial 3	1.30	1.29	1.47	.246
Fine Motor	1.08	1.16	1.65[b]	.001[c]
Wallin Pegboard-right hand	1.01	1.03	1.30[b]	.001
Wallin Pegboard-left hand	1.02	1.03	1.10[b]	.046
Copy forms-circle	1.03	1.06	1.18[b]	.001[c]
Copy forms-cross	1.19	1.26	1.58[b]	.001
Copy forms-square	1.80	1.88	1.89	.213
Stringing Beads	1.05	1.10	1.32[b]	.001[c]
Porteus Maze IV	1.21	1.28	1.53[b]	.013
Behavioral	1.29	1.24	1.74[b]	.004
Overall Impression	1.22	1.30	2.04[b]	.001

Note. Analysis of covariance used Socioeconomic Index scores as the covariate.

[a]Group I significantly different from Groups II and III

[b]Group III significantly different from Groups I and II

[c]Groups I, II, and III all significantly different from each other.

Table 3

Distributions and Analysis of Covariance of Means of Stanford-Binet and WISC IQ Scores and 7-Year Neurological Ratings for Neurologically Normal and Abnormal Subjects

Measures	Neurological Groups I	II	III	
	%	%	%	p
4-yr. Binet				
<70	1.0	1.9	31.8	
70-89	13.8	19.4	18.2	
90-110	50.2	51.6	40.9	
111-130	29.9	27.1	9.1	
131+	5.2	1.2	0	
$\bar{X}$	105.1	101.2	82.5[a]	.001
7-yr. WISC				
<70	0.7	1.3	21.1	
70-89	10.9	21.4	31.5	
90-110		52.6	31.6	
111-130	27.7	24.7	15.9	
131+	2.6	0.7	0	
$\bar{X}$	104.1	101.7	87.9	.001[b]
7-yr. Neurological Exam				
0 (Normal)	83.2	75.5	36.4	
1 (Suspect)	15.6	15.2	13.6	
2 (Abnormal)	1.1	9.3	50.0	
$\bar{X}$	.18	.34	1.14	.001

Note. Analysis of covariance used Socioeconomic Index scores as the covariate.

[a]Group III significantly different from Groups I and II

[b]Groups I, II, and III all significantly different from each other

Table 4

Analysis of Covariance of Mean Scores of Neurologically Normal and Abnormal Subjects on Measures of School Readiness, Language Development, and School Achievement

	Neurological Groups			
	I	II	III	
Measures	$\overline{X}$	$\overline{X}$	$\overline{X}$	p
5-yr. MRT	30.5	27.6	17.5	.008[c]
" ITPA	60.2	57.0	46.6[b]	.001[c]
6-yr. MRT	56.4	54.3	36.4[b]	.001
" ITPA	74.5	72.8	53.7[b]	.001
7-yr. WRAT Reading	36.3	33.8	27.5[b]	.036
" " Spelling	24.9	23.7	20.1	.020
" " Arithmetic	20.8	20.2	17.8	.018
9-yr. SAT Reading	23.4[a]	20.9	16.7	.001
" " Spelling	16.7[a]	14.2	9.5	.005
" " Arithmetic	26.5[a]	23.4	16.7	.007
12-yr. WRAT Reading	76.3	74.6	63.7	.001
" " Spelling	46.7	45.0	39.0	.001
" " Arithmetic	37.8[a]	36.1	31.4	.001
" SAT Reading	27.3	25.0	18.0	.001
" " Arithmetic	17.2	14.7	11.3	.001

Note. Analysis of covariance used Socioeconomic Index scores as covariate.

[a]Group I significantly different from Groups II and III

[b]Group III significantly different from Groups I and II

[c]Groups I, II, and III all significantly different from each other

Table 5

Analysis of Covariance of Teacher Behavior Ratings and Mean Number of Special School Services and Placements Received by Neurologically Normal and Abnormal Subjects During the Elementary School Years

	Neurological Groups			
	I	II	III	
Services	$\overline{X}$	$\overline{X}$	$\overline{X}$	p
Psychological	.15[a]	.23	.40	.002
Social Work	.05	.06	.00	.422
Special Class	.11	.12	.45[b]	.001
Speech	.15	.21	.30	.116
Medical	.11	.13	.20	.517
Tutorial	.19	.22	.40	.366
Remedial Reading	.19	.20	.40	.298
Total Number of Services	.95	1.17	2.15[b]	.001
Retention	.15	.15	.30	.231
Teacher Behavior Ratings	1.60	1.70	1.90	.502

Note. Analysis of covariance used Socioeconomic Index scores as covariate.

[a]Group I significantly different from Groups II and III

[b]Group III significantly different from Groups I and II